Shell Model Study of Exotic Nuclei near ^{132}Sn

Rakhi Mukhopadhyay [1*], S Sarkar[2] and M. Saha Sarkar[2]
[1]*Dum Dum Motijheel College, Kolkata- 700074, INDIA*
[2]*Indian Institute of Engineering Science and Technology, Shibpur, Howrah - 711103, INDIA*
[3]*Saha Institute of Nuclear Physics, Kolkata-700064, INDIA*
** email: rakhi5@rediffmail.com*

Introduction

The study of nuclei around doubly closed shell ones plays an important role in testing the predictive power of shell model. ^{208}Pb is a doubly closed shell nucleus on the line of stability. Lot of theoretical and experimental works in this region have been done and are still continuing.

There is an observation by Blomqvist [1], in which he pointed out that there should be many points of similarity between the spectroscopy of doubly closed shell regions around ^{208}Pb and ^{132}Sn. The single particle orbits above and below the shell gap of ^{132}Sn and ^{208}Pb are similarly ordered. Every single particle orbit in the ^{132}Sn region has its counterpart in the ^{208}Pb region, with same radial quantum number but one unit larger values of angular momentum l and j. As a consequence, the effective interactions used in case of ^{208}Pb region can be used for nuclei in the neighbourhood of ^{132}Sn after some modifications.

Recent advances in spectroscopy of exotic nuclei have led to experimental information for numerous areas in the periodic table which were previously not studied and even considered inaccessible. Doubly closed ^{132}Sn exhibits strongest shell closure and it lies well away from the line of stability. Recently, experimental information on the spectroscopic properties of nuclei in this region is being available from fission product γ- spectroscopy along with updated radioactive ion beam facilities with highly efficient detector arrays. It may therefore be of interest to calculate theoretically the spectroscopic properties of nuclei in this region and compare with the recent data. This type of study provides the opportunity to extract nucleon- nucleon interaction, as well as to test the theoretical shell model description of nuclear structure in this region.

We already presented the results of our study on the structure of $^{206, 204, 202}$Pb [2]. Our present work is an extension of the previous work. Here we applied the same interaction to study the structure of the exotic neutron rich nuclei around ^{132}Sn. Here the hole energies are replaced with single particle energies, which only involves inversion of sign of the values. The excitation energies, transition probabilities, magnetic and quadrupole moments of ^{134}Sn, ^{136}Sn and ^{138}Sn are calculated and compared with experimental results. Incidentally, the experimental results on ^{136}Sn and ^{138}Sn have come very recently from experiments carried out at the RIKEN Radioactive Isotope Beam Factory (RIBF) [3, 4].

Shell model calculations

We have performed the calculation using OXBASH code [5] taking Pb206jb Hamiltonian by replacing the hole energies with single particle energies obtained from the excitation spectrum of ^{133}Sn. The energies in MeV are -0.8944, -2.4553, -0.4507, -1.6016, -0.7996 and 0.2397 for $1h_{9/2}$, $2f_{7/2}$, $2f_{5/2}$, $3p_{3/2}$, $3p_{1/2}$ and $1i_{13/2}$, respectively.

Results and Discussions

Binding Energy (B.E.) or nuclear mass information is a fundamental input for testing nuclear models. The masses of the nuclei around doubly closed shells are especially useful in testing the models due to their simple structure.

We have calculated the B.E and excitation energies in MeV and transition probabilities in e^2fm^4 unit for the neutron rich isotopes ^{134,136,138}Sn and compared the results with experimental data (Table: 1 and 2). Very recently, experimental results for ^{136}Sn and ^{138}Sn are published [3, 4].

Table 1: Comparison of Excitation energies

Nucleus	J^π	Energy (MeV)	
		Expt. [6]	Calc.
^{134}Sn	0^+	0.0	0.0
	2^+	0.725	0.817
	4^+	1.073	1.118
	6^+	1.247	1.235
	8^+	2.508	2.528
^{136}Sn	0^+	0.0	0.0
	2^+	0.688	0.825
^{138}Sn	0^+	0.0	0.0
	2^+	0.715	0.883

Table 2: Comparison of B(E2)s.

Nucleus		B(E2) (e^2fm^4)	
		Expt. [6]	Calc.
^{134}Sn	$0^+ \rightarrow 2^+$	290(50)	276.6
	$6^+ \rightarrow 4^+$	36(7)	27.7
^{136}Sn	$0^+ \rightarrow 2^+$		495.1
^{138}Sn	$0^+ \rightarrow 2^+$		613.8

The results show interesting features. For ^{134}Sn, the theoretical results for energies (Table 1) agree quite well with experimental value, especially for higher J^π. The transition probabilities (Table 2) also show very good agreement with experimental data. The neutron effective charge has been taken to 0.64e for all calculations.

Conclusion

The results are encouraging. The transition probabilities for $6^+ \rightarrow 4^+$ transitions in cases of ^{136}Sn and ^{138}Sn will be calculated to compare with the recent experimental value [3, 4].

We have a plan to extend our study for Pb isotopes with A<202, motivated by the recent theoretical shell model calculation [7]. In this calculation [7], the same model space as that of ours has been considered with a different interaction. These results will eventually lead to predictions for more exotic isotopes of Sn.

References

[1] J. Blomqvist *et al*., Phys. Lett. **18**, 47 (1965).
[2] R. Mukhopadhyay, S. Sarkar, M. Saha Sarkar; Proc. DAE-BRNS symp. Nucl Phys (India) **53,** 329 (2008).
[3] He Wang *et al.*, Prog. Theor. Exp. Phys. 023D02 (2014)
[4] G. S. Simpson *et al.*, Phys. Rev. Lett. **113**, 132502 (2014)
[5] B. A. Brown *et al.*, MSU- NSCL Report No. 524, (1985).
[6] www.nndc.bnl.gov
[7] Chong Qi *et al.* Phys. Rev. C **94**, 014312 (2016).